Customer No. 27061 Patent
Confirmation No. Attorney Docket No. GEMS8081.169

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of	:	Saranathan et al.
Serial No.	:	10/604,829
Filed	:	8/20/2003
For	:	MULTI-SLICE MR DATA ACQUISITION IN SUCCESSIVE HEARTBEATS WITH BLACK BLOOD CONTRAST
Group Art No.	:	3737
Examiner	:	Mehta, Parikha

CERTIFICATION UNDER 37 CFR 1.8(a) and 1.10

I hereby certify that, on the date shown below, this correspondence is being:

Mailing

□ deposited with the US Postal Service in an envelope addressed to Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450

37 CFR 1.8(a) **37 CFR 1.10**

□ with sufficient postage as first class mail □ As "Express Mail Post Office to Addressee" Mailing Label No.

Transmission

□ transmitted by facsimile to Fax No.: 571-273-8300 addressed to **Examiner Parikha Mehta** at the Patent and Trademark Office.

■ transmitted by EFS-WEB addressed to **Examiner Parikha Mehta** at the Patent and Trademark Office.

Date: December 4, 2007 /Robyn L. Templin/
Signature

DECLARATION UNDER 37 C.F.R. §1.131

We, being duly sworn, depose and say:

1. That we are the inventors for the above-identified Patent Application;

2. That we have reviewed the claims of this Application;

3. That we conceived the invention as set forth in the aforementioned claims in the United States prior to June 26, 2003, the effective date under 35 U.S.C. § 102(e) of the cited United States Patent Application Publication No. 2005/0010104 to Fayad et al.;

4. That, prior to said date, we conceived of a method of multi-slice image acquisition with black blood contrast, the method comprising the steps of applying a non-selective inversion pulse in successive R-R intervals and applying a re-inversion pulse in the successive R-R intervals that is slice-selective over a region encompassing a plurality of slice selections. The method includes timing execution of a series of RF excitation pulses such that signal from blood is near a null point in each R-R interval and acquiring data of at least two slices for each application of the re-inversion pulse in the successive R-R intervals;

5. That, prior to said date, we also conceived of a computer readable storage medium having a computer program stored thereon, the computer program representing a set of instructions that when executed by a computer causes the computer to generate and cause application of a non-selective inversion pulse applicable to a slab of slices, the non-selective inversion pulse to be applied in each R-R interval and to generate and cause application of a slice-selective re-inversion pulse applicable to the slab of slices applied after each non-selective inversion pulse. The set of instructions also causes the computer to generate and cause application of a series of spin echo readout excitation pulses applicable to the slab of slices such that MR data with black blood contrast is acquired of a first set of at least two slices of the slab during a first R-R interval after application of a respective single slice-selective re-inversion pulse and of a second set of at least two slices of the slab during a next R-R interval after application of a respective single slice-selective re-inversion pulse;

6. That, prior to said date, we also conceived of an MRI apparatus comprising a magnetic resonance imaging (MRI) system having a plurality of gradient coils positioned about a bore of a magnet to impress a polarizing magnetic field and an RF transceiver system and an RF switch controlled by a pulse module to transmit RF signals to an RF coil assembly to acquire MR images. The MRI apparatus also comprises a computer programmed to apply a pulse sequence having a first and a second inversion pulse during each heartbeat of a successive train of heartbeats and a series of readout excitation pulses during each heartbeat of the successive train of heartbeats such that at least two slices of data with black blood contrast are acquired for each application of one

of the first and the second inversion pulses during each heartbeat of the successive train of heartbeats;

7. That, prior to said date, we also conceived of a computer readable storage medium having a computer program stored thereon, the computer program representing a set of instructions that when executed by a computer causes the computer to generate and cause application of a non-selective inversion RF pulse to a slab of slices during successive R-R intervals, generate and cause application of a slice-selective re-inversion RF pulse to the slab of slices during successive R-R intervals, and delay data acquisition in each R-R interval by an inversion time sufficient to allow magnetization of blood within the slab to substantially reach a null point. The set of instructions also causes the computer to apply a series of RF excitation pulses in each R-R interval and acquire MR data for at least two slices in the slab for each slice-selective re-inversion RF pulse in each R-R interval;

8. That, prior to said date, we also conceived of a computer readable storage medium having a computer program stored thereon, the computer program representing a set of instructions that when executed by a computer causes the computer to generate and cause application of a non-selective inversion pulse to be carried out in each R-R interval of a train of R-R intervals and generate and cause application of a slice-selective re-inversion pulse to be carried out after the non-selective inversion pulse in each R-R interval. The set of instructions also causes the computer to generate and cause application of a set of excitation pulses to be applied in each R-R interval such that MR data may be acquired for at least two slices in a slab during each R-R interval and for each slice-selective re-inversion pulse;

9. Attached as Exhibit A is a copy of our disclosure to our employer that was prepared prior to June 26, 2003 and evidencing this invention;

10. That from prior to June 26, 2003 to August 20, 2003, the filing date of the above-reference Patent Application, we diligently worked toward reducing the aforementioned inveniton to practice and worked with patent counsel in the preparation of a patent application of the claimed invention; and

11. That the statements made herein are of our own knowledge and are true and made on information and belief that are believed to be true.

We acknowledge that any willful false statements and the like made herein are punishable by fine or imprisonment, or both, and may jeopardize the validity of the application or any patent issuing thereon.

S. Manojkumar

Manojkumar Saranathan

Dated: Nov 30 2007

Glenn S. Slavin

Dated: _____

We acknowledge that any willful false statements and the like made herein are punishable by fine or imprisonment, or both, and may jeopardize the validity of the application or any patent issuing thereon.

_____ Dated: _____

Manojkumar Saranathan

_____ Dated: 12/3/07

Glenn S. Slavin

Exhibit A

GE Medical Systems
Invention Disclosure Form

3000 North Grandview Blvd., W-710
P.O. Box 414, Waukesha WI 53188
(262) 544-3028; Dialcom: 8*320-3028

Docket No.: 132152

Mail to: PATENT OPERATION, W-710

Date Received: [redacted]

- **Use as many pages in this word document as necessary.**
- **You may attach additional materials to support this disclosure, for example, Tech Notes and Drawings. Such submitted materials must be referenced in this disclosure form. Each page of these materials must be dated, signed and witnessed in the same manner as this invention disclosure.**

MODALITY: *(e.g., CT, MR, Ultrasound, X-Ray)*

MR

INVENTION TITLE: *Provide a unique, descriptive title. If you write this disclosure in a language other than English, please provide a title in English as well. Si vous rédigez en français, merci de proposer un titre en anglais et un titre en français.*

A method for improving the efficiency of double inversion recovery black-blood imaging.

PROBLEM/BACKGROUND: *Describe the problem that is solved by the invention. Assume that the reader has a basic knowledge of your diagnostic imaging modality and related technologies.*

Black blood imaging sequences are employed in clinical magnetic resonance imaging (MRI) of the heart and vasculature to characterize plaques, valve abnormalities and other congenital defects like right ventricular dysplasia. A double inversion recovery (DIR) prepared Fast Spin Echo sequence (FSE) is most commonly employed for this purpose. This sequence is illustrated in Figure 1. A non-selective 180° inversion pulse inverts the magnetization of blood and tissue everywhere and the re-inversion pulse restores the magnetization in the tissue of interest i.e. the excited slice. If this DIR segment is placed prior to systole, the systolic contraction will cause inverted blood to flow into the slice and non-inverted blood in the slice to flow out of the slice. If the acquisition of the slice is performed when the blood magnetization is crossing the zero point, blood in the imaged slice will be "black". Notice that every other heart beat is utilized for the inversion and acquisition to allow the magnetization to relax between successive inversions. For a typical cardiac examination (256 readout points, 192 phase encodes, ¾ phase FOV, echo train length (ETL)=12-16), the scan time is 18-24 heartbeats. In order to minimize respiratory artifacts, the images are acquired during an end-expiratory breath-hold. In order to achieve sufficient coverage, 8-12 contiguous slices are acquired in successive breath-holds, which can be very exhausting for patients. We propose a modified pulse sequence that can reduce the total scan time by a factor of 4, by enabling the acquisition of 4 slices per breath-hold, rather than just 1. This allows the exam to be completed in 2-3 breath-holds instead of 8-12 breath-holds it currently takes.

INVENTION DESCRIPTION: *Describe how the invention works and how it solves the problem posed above.*

INVENTORS *(Print or Type Name Below)*	*(Full Signature Below)*	**GE**	**NOT GE**	**DATE**
Manojkumar Saranathan		X		
Glenn S. Slavin		X		

* = Primary Contact Inventor (to coordinate with Patent Evaluation Board and Preparing Attorney)

Read and Understood By:

2 WITNESSES (Mandatory) *(Print or Type Name Below)*	*(Full Signature Below)*	**DATE**

The proposed modification involves using every R-R interval for inversion and acquisition of the data instead of using every other R-R interval as is done in conventional DIR FSE sequence. In each R-R interval (heart beat), following the non-selective 180° pulse, a selective 180° pulse is played out to re-invert a slab that contains the 4 slices to be imaged. After a delay TI where blood goes through a null, *k*-space data for slices 1 and 2 are acquired in the first R-R and slices 3 and 4 in the second R-R, repeating until all of k-space is acquired. Note that the tissue for each slice is still excited only during *every other* R-R interval and hence there is no SNR loss. Blood TI, however, is shortened due to its excitation during *every* R-R interval. As a result the acquisition of the first slice occurs during late-systole/early diastole. This could result in slice mis-registration and a resulting loss of tissue signal as the re-inversion pulse is played out during late diastole. However, by shifting the start of the sequence (non-selective 180° pulse) by 100-150 ms, this effect can be ameliorated. If peripheral pulse gating is employed, the need for this shift is obviated because of the inherent delay between the peripheral pulse and the R-wave of the order of 100ms.

INVENTORS *(Prnt or Type Name Below)*	*(Full Signature Below)*	GE	NOT GE	DATE
Manojkumar Saranathan		X		
Glenn S. Slavin		X		

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DRAWING: *Make as accurate a sketch or computer generated figure of your invention as you can and embed it into or attach it to this form. It need not be a drawing to scale, but should be complete enough to show what you have in mind. If you already have suitable photographs, sketches, software flowcharts or finished drawings, they may be used.*

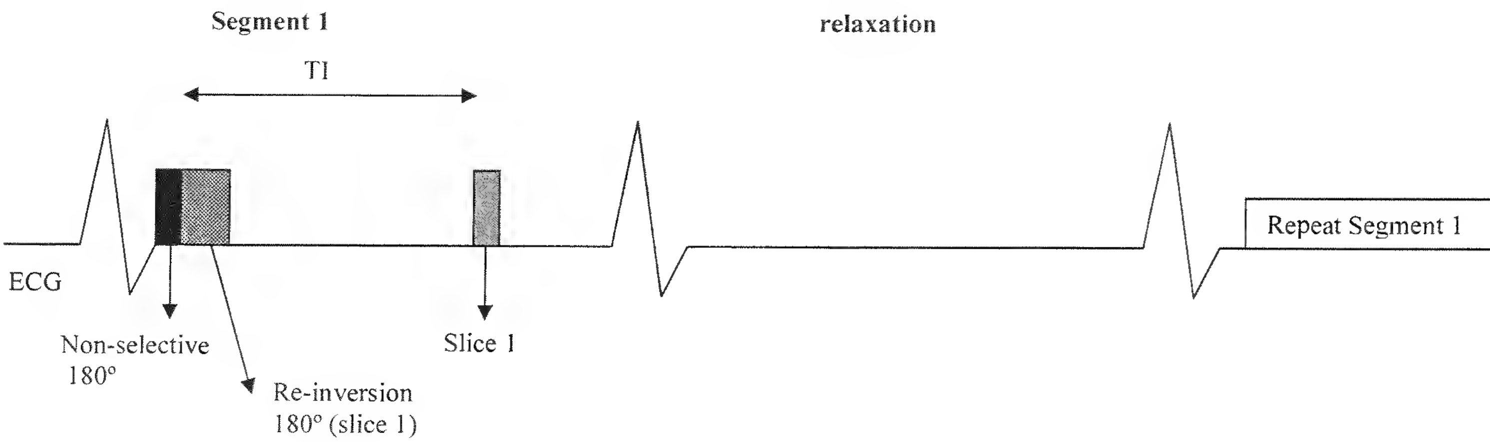

Figure 1. Schematic of a conventional black blood sequence using double IR FSE: In the first R-R interval (heart beat), following the non-selective 180° pulse, a re-inversion 180° pulse is played. After a delay TI where blood goes through a null, *k*-space data is acquired. The equilibrium magnetization is allowed to recover in the next R-R interval. This is repeated until all data are acquired.

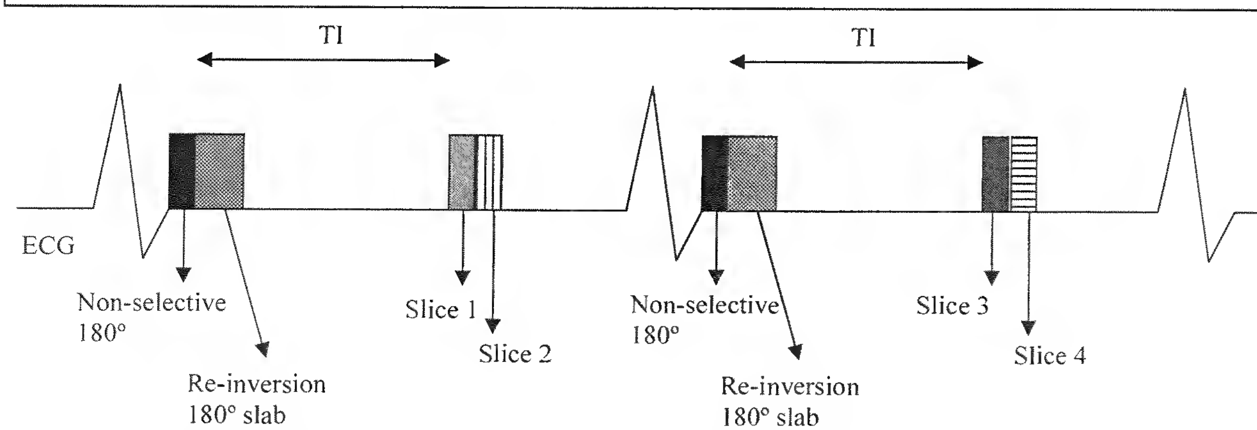

Figure 2. Schematic of the proposed sequence: In each R-R interval (heart beat), following the non-selective 180° pulse, a re-inversion 180° pulse is played to re-invert a slab containing all 4 slices of interest. After a delay TI where blood goes through a null, *k*-space data for the slices 1-2 is acquired in the first R-R and slices 3-4 in the second R-R and so on. Note that the tissue for each slice is now excited every other R-R and hence no SNR loss is expected. Blood TI is however shortened due to its excitation in every R-R interval.

Manojkumar Saranathan		X		
Glenn S. Slavin		X		

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ADVANTAGES OF THE INVENTION: *Describe the benefits of the invention, both in technical terms (e.g., stronger, new application, faster imaging, etc.) and business terms (e.g., cost savings, product efficiency, etc.).*

Since the data acquisition is performed every R-R and two slices are acquired in each R-R, the total acquisition time can be reduced by a factor of 4, minimizing patient discomfort. Each slice-pair is excited only during every other R-R resulting in no SNR loss for tissue signal compared to conventional imaging.

PRIOR ART: *List all references to previous work that you have identified that relate to the invention (if any). Examples would be existing patents (whether GE or other) possibly identified via patent searches, GEMS invention disclosures in*

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Glenn S. Slavin		X		

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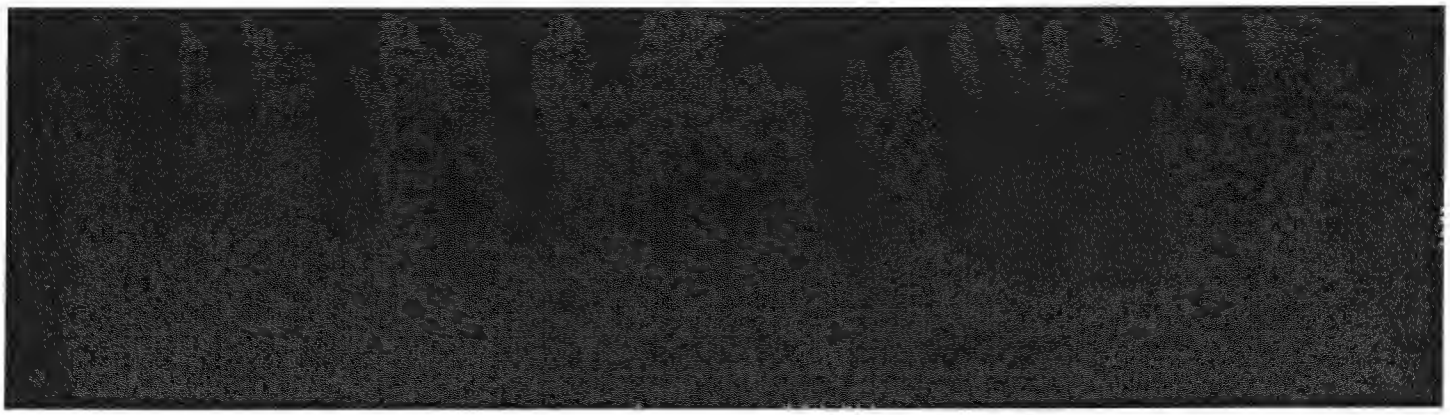
Read and Understood By:

2 WITNESSES (Mandatory) *(Print or Type Name Below)*	*(Full Signature Below)*	DATE

process or otherwise, existing products, publications, internal publications, or Tech Notes etc. All identified prior art references must be attached to this disclosure, but those pages need not be signed.

1. Song HK et al. Multislice double inversion pulse sequence for efficient black-blood MRI. Magn Reson Med. 2002 Mar;47(3):616-20.



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